ANNEX 7

REPORT OF THE WORKING GROUP ON STATISTICS, ASSESSMENTS AND MODELLING

(Christchurch, New Zealand, 9 to 13 July 2007)

CONTENTS

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INTRODUCTION

Opening of the meeting

The first meeting of WG-SAM was held at the Latimer Hotel, Christchurch, New Zealand, from 9 to 13 July 2007. The meeting was co-convened by Drs C. Jones (USA) and A. Constable (Australia). WG-SAM, which replaces WG-FSA's Subgroup on Assessment Methods, was established by the Scientific Committee in 2006 to serve as a technical group to address quantitative and modelling issues relevant to all Scientific Committee working groups (WG-FSA, WG-EMM and ad hoc WG-IMAF) (SC-CAMLR-XXV, paragraphs 13.12 to 13.16).

1.2 Dr Jones welcomed participants (Appendix A) and thanked New Zealand for hosting the meeting. Miss J. McCabe, on behalf of the New Zealand Ministry for Foreign Affairs and Trade, also welcomed the participants.

Adoption of the agenda and organisation of the meeting

1.3 The provisional agenda was discussed and it was agreed to include consideration of by-catch species under Item 3 (Assessment Methods). It was also agreed that subitems 3.1 (New Methods for CCAMLR Taxa) and 5.1 (Development of Operating Models) would be discussed with respect to the taxa identified in the respective agenda items. As a result, subitems 3.1 and 5.1 were removed from the agenda. The revised agenda was adopted (Appendix B).

1.4 Documents submitted to the meeting are listed in Appendix C.

1.5 The report was prepared by Drs I. Ball (Australia), A. Brandão (South Africa), S. Candy (Australia), Mr A. Dunn (New Zealand), Drs M. Goebel (USA), S. Hanchet (New Zealand), S. Hill (UK), R. Hillary (UK), R. Holt (USA), S. Mormede (New Zealand), É. Plagányi (South Africa), D. Ramm (Data Manager), K. Reid (UK), C. Reiss (USA), G. Watters (USA) and D. Welsford (Australia).

PARAMETER ESTIMATION

Refinements of existing methods

2.1 Mr Dunn presented WG-SAM-07/5, which updated the descriptive analysis of the toothfish tag–release and recapture data for New Zealand vessels for the 2006/07 season in Subareas 88.1 and 88.2.

2.2 The Working Group welcomed the analysis and recommended that similar papers be prepared for WG-FSA-07 that provide a descriptive analysis of the tagging program in Division 58.5.1, and papers that update the descriptive analyses of tagging programs in Division 58.5.2 and Subarea 48.3.

2.3 It was noted that there were disparities between the recapture rates of tags by different vessels across the fishery in Subareas 88.1 and 88.2. The spatial structure of the fishery, with vessels fishing the same areas in successive years, may result in a tendency for vessels to recapture their own tags. It was recommended that these differences be analysed and that a method be developed to describe the spatial pattern of tag recaptures including the vessels which released tagged fish and the vessels recapturing tagged fish.

2.4 The Working Group recommended that a spatial movement model be constructed in order to answer questions about the efficacy of the tagging program and the best manner of interpreting the data. The model could also be used to determine the best way to maximise the information output in a way useful for the integrated assessment method.

2.5 The Working Group was asked whether it had any advice on whether the current level of tagging was reasonable or if it should be increased. Mr Dunn noted that the level of tagging appeared to be a reasonable balance between increasing the number of tagged fish in the population and ensuring that the tagging program remains of high quality. Dr K. Sullivan (New Zealand) noted that: early tags are still being recovered, the number of tagged fish in the population is still increasing, and the amount of information arising from tag recaptures is increasing each year.

2.6 The Working Group noted that the Secretariat would take responsibility for coordinating tagging programs in new and exploratory fisheries starting from the 2007/08 season. It recommended that WG-FSA consider the development of advice on how it should manage the collection of non-toothfish tagging data, particularly from voluntary tagging programs.

2.7 Dr Welsford described the triple tagging of fish in the fishery in Division 58.5.2 using passive integrated transponder (PIT) tags to assist in evaluating external tag observation and shedding rates. The Working Group recommended that a paper be prepared which described this methodology and results.

2.8 Mr Dunn presented WG-SAM-07/6 which reviewed and updated the catch history, CPUE indices, length–weight relationships, catch-at-length and catch-at-age frequencies and included a review of alternative methods for the stratification of length frequencies for *Dissostichus mawsoni* in the Ross Sea.

2.9 It was noted that scientific observer data from a small number of vessels had a large proportion of unsexed fish. The use of an unsexed length–weight relationship resulted in little change to estimated length-frequency distributions. However, an alternative method of scaling length-frequency samples, making use of the number of fish caught instead of the catch weight, resulted in some differences to the estimated distributions. Mr Dunn noted that scaling by catch numbers is preferable as it avoids the need to apply a length–weight relationship to estimate sample weight.

2.10 The Working Group agreed that it would be useful in the future to use samples from recaptured tagged fish to determine the age–length relationship of tagged fish in order to examine differences in the growth rates between tagged and non-tagged fish and determine a suitable value for a tag-related growth retardation parameter.

New methods

2.11 The Working Group welcomed a paper by Dr Candy (WG-SAM-07/7) presenting a new method for the calculation of effective sample size. In discussion on the comparison between the new method and existing methods, some notational errors were discovered in the documentation of existing methods.

2.12 During the meeting the implementation of the existing methods, as given in WG-SAM-07/7, was changed by Dr Candy to reflect the correct notation and the resultant differences between the methods, apart from issues relating to process error, were no longer a significant issue for assessments.

2.13 With respect to the important issue of quantifying the relative contributions of process error and systematic lack of fit, Dr Candy demonstrated a method to detect statistically significant systematic lack of fit of integrated model predictions of catch-at-age or catch-at-length frequencies. The Working Group encouraged the development and documentation of this approach for general use.

2.14 WG-SAM noted the report of the 2007 meeting of SG-ASAM, and the further progress made in developing the methodologies for acoustic surveys of icefish (*Champsocephalus gunnari*) (Annex 8). In particular, WG-SAM noted that further work is required on species classification and target strength before it would be feasible to consider methods for combining trawl and acoustic indices for stock assessment of icefish in Subarea 48.3.

2.15 WG-SAM noted the hierarchical procedures for the collection of acoustic data during CCAMLR-related IPY surveys which had been developed during a joint session of SG-ASAM and the CCAMLR-IPY Steering Committee.

2.16 WG-SAM noted the report of the 2007 planning meeting of the CCAMLR-IPY Steering Committee (SC-CAMLR-XXVI/BG/3) and the CCAMLR-related research.

ASSESSMENT METHODS

Dissostichus spp.

3.1 WG-SAM-07/8 proposed a methodology for a preliminary assessment of toothfish on BANZARE Bank (Division 58.4.3b). Preliminary analysis of non-standardised CPUE data showed evidence of severe depletion in one fishing ground where catch and effort had concentrated from the 2004 to the 2007 seasons. It was suggested that the CPUE time series

has some variability and is not necessarily simply decreasing, but that the spatial aggregation in catch and effort would need to be considered as a factor in any overall trends in CPUE seen in this fishery.

3.2 The Working Group agreed that it was important to consider the very high level of IUU catches in this division, which needs to be considered in interpreting the results of a depletion analysis to determine stock biomass.

3.3 A highly spatial relationship between by-catch (rajids and macrourids) and the toothfish fishery, given the figures displayed in the paper, was noted by the Working Group. However, it was also noted that this was not the same relationship for both of these by-catch species.

3.4 The Working Group agreed that a fine-scale standardisation of the CPUE data, to be applicable to such a depletion-type model, would be a good way to proceed so as to obtain a CPUE dataset that can be used in such a Leslie-DeLury depletion analysis. It was noted that what can be seen in the paper is an analysis of the status of the population in the given grounds, i.e. the vulnerable stock, and not the size of the population as a whole. The interpretation of stock in this case could be the summation of the stock sizes in the relevant areas, but it was mentioned that this assumption should be made explicit in further analyses. The Working Group agreed that a Leslie-DeLury depletion analysis could be considered in providing advice on potential yields in exploratory toothfish fisheries depending on broader consideration of the application of CCAMLR's precautionary approach in those fisheries.

3.5 With respect to IUU fishing, the timing of such fishing is very relevant to the potential impact of IUU catches on the results coming from this type of approach. If the IUU catches were taken during the period of the legal fishery, then the rate of decline in CPUE will not be as great as indicated in WG-SAM-07/8. However, if the IUU catches were outside the fishing period, then the rate of decline in CPUE would reflect the rate of decline in the local vulnerable population. The timing and magnitude of IUU fishing is best addressed by SCIC, but it was noted that basic sighting plots of IUU vessels might be informative with respect to the effect of IUU fishing on the patterns of decreasing CPUE, seen at the scale of the grounds as described in WG-SAM-07/8.

3.6 One concern expressed by the Working Group was the lack of small fish seen in this fishery. Knowledge of how these stocks are replenished by recruitment would help the assessment. In particular, it was important to identify the origin of the recruits in order to be confident that fisheries were not over-exploiting the stock through fishing on both the recruits and the adults as if they were separate stocks.

3.7 Further work to consider the links between fished stocks in Subarea 58.4 was agreed to be worthwhile.

3.8 The authors of WG-SAM-07/9 were not present at the meeting but the paper was discussed with respect to the general methodology. It was noted that the general interpretation of both methods and results of any type of model is very difficult without the display of both the data entered into the model, and how well these data are fitted by the proposed assessment model. It was agreed that there are many questions on the applicability of a TSVPA approach, including whether the complexity of these VPA methods was warranted, how tagging data can be included in the model, and the methods by which the

input data are calculated. The Working Group agreed that it is very hard to appraise such a paper without the presence of the authors, given the difficulty in understanding the many aspects of the data and methods applied in this paper. The Working Group also agreed that new methods that are suggested as alternatives to assessments that have already been through a review process within WG-FSA (including WG-FSA-SAM, the precursor to WG-SAM) must follow the general guidelines detailed in paragraph 6.3.

Champsocephalus gunnari

3.9 In 2006, WG-FSA identified the following items to further develop the assessment of *C. gunnari* (SC-CAMLR-XXV, Annex 5, paragraphs 12.13 and 12.14):

Fishery in Subarea 48.3:

- investigation of the consequences and solutions to setting catch limits which might result in high harvesting rates on small, unassessed, recruiting year classes;
- further development of the acoustic protocol for assessing biomass;
- continued assessment of accuracy and precision of otolith-based age estimates.

Fishery in Division 58.5.2:

- review of biological parameters and cohort progression based on survey and catch data.

3.10 WG-SAM agreed that it could address some of these items at future meetings and in the light of findings from the forthcoming joint WG-FSA and WG-EMM Workshop on Fisheries and Ecosystem Models in the Antarctic (SC-CAMLR-XXVI/BG/6; Annex 4, paragraphs 7.6 to 7.8).

Euphausia superba

3.11 In 2006, the Scientific Committee requested that the Working Group undertake the following with respect to krill assessments:

(i) contribute to the review of the most appropriate method for estimating B_0 and associated CV from survey data for the B_0 workshop to be held as part of WG-EMM following this meeting (SC-CAMLR-XXV, paragraph 3.27);

(ii) explore whether an integrated assessment approach could be undertaken for krill, similar to that used by WG-FSA for other species (SC-CAMLR-XXV, paragraph 3.15).

3.12 The Working Group noted that the following could be considered in an integrated assessment for krill:

(i) Stock structure –

(a) flows in the region indicate that krill is likely to be transported through the region such that relevant models should include spatial structure;

(b) there is some uncertainty as to whether there are single or multiple stocks of krill;

(c) the assessment should be of the vulnerable (rather than total) population as the system is not closed. An integrated assessment model would thus need to include both emigration and immigration terms.

(ii) Fishery –

(a) there are seasonal differences in the krill fishery, with a winter fishery operating around South Georgia and a summer fishery in other regions;

(b) data for an integrated assessment would need to be provided separately for each fishing subarea (South Shetland Islands, South Orkney Islands and South Georgia), which was considered feasible given that data are available on a haul-by-haul basis.

(iii) Research data –

(a) data for an integrated assessment could be provided by routine surveys undertaken by the British Antarctic Survey in the South Georgia area together with US AMLR surveys in the Antarctic Peninsula region;

(b) it may be worthwhile to examine concordance between different krill survey time series to try and estimate movement rates.

(iv) Assessment –

(a) a move to a finer-scale model requires a much larger and more complex model which, in practice, can be difficult to implement given computational constraints;

(b) at present, this may not be sensible, but it may become increasingly important to divide the region into at least three areas as the fishery starts to approach the catch limit for the entire region;

(c) data currently collected need to be of sufficient quality for future work. It was suggested that it might be useful to construct what an integrated model might look like to advise on data needs. In trying to fit such a model to all different datasets (such as that pertaining to growth dynamics), the Working Group agreed that it would likely be necessary to step back in model complexity and simplify assumptions, for example, by fitting to size-frequency data rather than developing a full growth model;

(d) spatial models were proposed as a tool which could assist by, for example, evaluating in which areas simplifying assumptions matter most;

(e) proposals to develop an integrated assessment should consider what the current limitations of the KYM are;

(f) it was recommended that the MSE approach would be the ideal approach to evaluate the utility and accuracy of an integrated assessment.

3.13 The Working Group agreed that the following were important data considerations in moving towards developing an integrated assessment:

(i) The length-frequency data that are currently available are mostly from surveys, with no obligation for the krill fishery to provide similar data. Given the longevity of krill, there is a need to collect data several years in advance of a model needing such data and hence it was recommended that the fishery start providing length-frequency data, given that coverage by the research surveys is not likely to be sufficient for all regions.

(ii) The collection of high-quality biological data from all commercial vessels is needed. It was noted that there are currently only five to nine trips per year from which such data are reported from commercial vessels.

By-catch species

3.14 Dr Hillary presented a preliminary assessment of rajid populations at South Georgia using a surplus production model implemented in a Bayesian framework (WG-SAM-07/11). First, a catch history for the rajid by-catch was developed, with an adjustment for the survivorship of rajids which had been cut off the lines ('cut-offs'). Then several standardised CPUE analyses were carried out for fleets fishing between 1993 and 2007. A surplus production model was fitted to the catch and CPUE indices. This model was used because there were insufficient tagging data to carry out an alternative modelling approach such as an integrated assessment. Priors were developed for each of the four parameters estimated in the model: K, r, Spanish longline q and autoline q. The prior for the carrying capacity K was derived from the assumption that the difference in catch rates between toothfish and rajids was directly proportional to the difference in abundance between the two species (i.e. they have the same q). The prior for r was derived from life-history parameters, and the priors for the two q parameters were derived assuming that the level of depletion of the stock at the time of the CPUE data was uniformly likely to be between 60 and 90% of K. The paper concluded that current catches were not significantly impacting the rajid population.

3.15 The Working Group noted that there were currently insufficient data to inform the assessment and that the results were strongly dependent on the informative priors for the two catchability parameters, and the intrinsic rate of increase, r. However, it also noted that the assessment was likely to be a 'worst-case' scenario, because the q for toothfish is likely to be higher than the q for rajids. The fits to the CPUE data were generally poor, and the posterior distributions for the two catchability parameters and r were very similar to their prior distributions in the base case. When an uninformed prior was used for K and the two q parameters, the right-hand tail of the posterior distribution of K was very wide. Dr Constable

questioned why the CPUE indices, in some years, showed a large increase then subsequent decrease and suggested splitting the assessment into two areas for CPUE analysis – Shag Rocks and northern South Georgia. The Working Group considered that the assessment may be improved if the tag data could be included as a tag-based harvest rate in the model.

3.16 Dr Hillary noted that the assessment should be considered as a risk assessment rather than a stock assessment. Dr Constable agreed and noted that it would be desirable to set up appropriate methodologies for a risk assessment consistent with the precautionary approach of CCAMLR but not necessarily undertake an assessment. The Working Group noted that an integrated assessment could be considered in the future once more tag data and catch-at-length data were available.

3.17 Mr Dunn outlined an approach for a preliminary assessment of rajid populations in the Ross Sea using an integrated assessment model in CASAL (WG-SAM-07/4). The assessment combined all rajid species because identification to species level has often not been carried out. The approach used to develop a catch history of rajid removals from the fishery took into account numbers of landed, released and tagged rajids. The numbers of released and tagged rajids were adjusted for survivorship so that the total removals from the population could be obtained. There was considerable uncertainty in the raw age–length data, so these data were fitted in the model allowing this uncertainty to feed through into an MCMC. He also identified several other problems with the data, including the paucity of length samples from the fishery, the uncertain detection rates of tags, and problems associated with the way rajids had been double-tagged.

3.18 As a result of these issues, WG-SAM-07/4 made the following recommendations:

- improve species identification by making good identification guides available to vessel crew and scientific observers;
- improve detection of tagged rajids (and species identification) by bringing rajids up to the roller before cutting them off;
- improve estimates of the catch length frequency by increasing the number of rajids measured and sexed;
- improve and validate the estimates of age and growth (for example, by the use of markers such as oxytetracycline or strontium chloride on tagged rajids, and/or by measuring rajids before release);
- revise rajid tagging protocols to encourage better survival of tagged rajids, including adding protocols for double tagging;
- undertake survivorship experiments, particularly for the different species, covering a wider range of depths, and with longer holding periods than the study of Endicott and Agnew (2004).

3.19 Dr Constable asked whether an assessment based on numbers rather than age-based biomass may be more useful in the short term because of the difficulties in ageing as well as the need for improved data collection by the observers. Dr Hillary noted that harvest rates could be estimated from the rajid recaptures, and did not need estimates of catches or the numbers of scanned fish. Dr Constable also asked about the stock structure. Mr Dunn noted

that tagging suggested rajids were quite localised and showed very little movement between release and recapture. Dr Hanchet noted that the bulk of the rajid catches were from SSRUs 881H, I and K, and that rajids from the southern shelf were primarily *Bathyraja* cf. *eatonii*, and that the current SSRU structure appeared suitable for the assessment and management of rajids.

3.20 The Working Group thanked the UK and New Zealand for their progress towards developing preliminary assessments for rajids, which has been an ongoing request by the Commission over the past few years (e.g. CCAMLR-XXV). The Working Group identified several common issues raised by the two papers. These issues related to species identification, catch sampling (the trade-off between sampling rajids for length and sex versus cutting them off the lines), improving estimates of age and growth, improving tagging protocols, and additional survivorship experiments. Several of these issues relate to the work of scientific observers. The Working Group acknowledged the heavy workload of the scientific observers and considered that the priorities for by-catch species may be better met by focusing each year on a particular species group. So that, for example, 2008/09 could be the 'Year of the Rajid', and 2009/10 could be the 'Year of the Macrourid'. The Working Group endorsed the need for further work in each of the areas identified by WG-SAM-07/4 and recommended that these issues be further addressed by WG-FSA.

REVIEW OF PRELIMINARY ASSESSMENTS FOR FINFISH

General

4.1 The Working Group considered fisheries where a preliminary assessment was not available at the meeting. It was suggested that details in previous reports as to how to improve existing assessments should be implemented, and that the ideas of the relevant scientists who are present and those likely to be performing, or assisting in, future assessments would be welcomed.

4.2 It was raised that it is not the purpose of this Working Group to discuss the type of data to be used in any proposed assessments, but rather the methods to be applied to these data, and that WG-FSA was the group that would review data inputs to stock assessment (Agenda Item 6.1).

Subarea 48.3

4.3 With regard to the assessment of Subarea 48.3, the Working Group noted potential plans to be completed between this meeting and WG-FSA-07. These plans will focus on the integration of catch-at-age data, and perhaps the inclusion of the survey data-at-length, as opposed to the CMIX-derived age estimates. The Working Group noted this may aid in estimating recent recruitment trends, as previous attempts have proved unsuccessful with respect to estimating a sensible historical recruitment trend.

Division 58.5.2

4.4 The Working Group was informed that the annual random stratified trawl survey was proceeding in Division 58.5.2, and an updated preliminary assessment would be presented to WG-FSA-07, including the data collected during the 2006/07 fishing season.

4.5 The Working Group noted the recommendations from WG-FSA-06 for the assessment of toothfish used to set catch limits in 2006/07 (SC-CAMLR-XXV, Annex 5, paragraphs 5.103 and 5.104).

4.6 The Working Group discussed the progress on the integrated assessment for toothfish in Division 58.5.2 using the CASAL framework. Dr Candy presented preliminary results from sensitivity tests based on the 2006/07 assessment, investigating the effects of:

(i) including less restriction in fitting selectivity functions to survey data;

(ii) removing strong prior assumptions on the CV of mean recruitment;

(iii) weighting datasets based on effective sample size analyses (described in WG-SAM-07/7) and fitting *q*;

(iv) incorporating tagging data and selectivity on tag releases.

4.7 A detailed technical discussion resulted in a recommendation that the assessment in Division 58.5.2 is likely to be improved through inclusion of ageing data, which would enable better estimation of recruitment and selectivity within the CASAL framework.

4.8 The Working Group affirmed the need for the further development of the assessment model, including further investigation of the sensitivity of the model to assumptions and constraints and some of these results may require further discussion. Dr Hanchet suggested using the tag data as an index of local abundance in comparison with the trawl data to develop an informed prior of the trawl survey *q*.

4.9 The Working Group recommended that a paper describing an updated assessment, based on the model framework provided at WG-FSA-06 and including the 2006/07 survey and fishery data, be prepared for consideration by WG-FSA-07.

Subareas 88.1 and 88.2 preliminary assessments

4.10 Mr Dunn presented WG-SAM-07/6, which described the impacts of changes in assumptions and data on the 2006 base-case model for *D. mawsoni* in the Ross Sea. These were: (i) updated catches for 2007; (ii) inclusion of IUU catch as reported in SC-CAMLR-XXV, Annex 5; (iii) updated CPUE indices for 2007; (iv) revised length–weight relationship for unsexed fish in determining catch-at-length frequencies; (v) revised catch length frequencies using numbers of fish rather than biomass; (vi) revised numbers of fish scanned; (vii) revised tag-related growth retardation parameter *g*; (viii) inclusion of a selectivity on tag–release length frequencies; and (ix) the inclusion of the tag data for 2007 from New Zealand vessels.

4.11 WG-SAM-07/6 also investigated alternative stratification of the Ross Sea fisheries, based on the catch length-frequency distributions. The paper found that the length-frequency distribution of *D. mawsoni* in the Ross Sea had a high degree of both large- and small-scale areal complexity. In general, the models typically split the Ross Sea into strata that were broadly similar to the current shelf, slope and north classifications. However, the resulting stratifications did not produce length frequencies that suggested consistent selectivity patterns over the duration of the fishery, in particular, in the slope or shelf regions. The report concluded that, while the current stratification (shelf, slope and north) had some deficiencies, revised stratifications did not appear to offer much improvement.

4.12 The Working Group noted that, in general, most of the assessment model changes noted in paragraph 4.10 had a negligible effect on the model outputs, with the most significant impacts on the assessment model results being: (i) the inclusion of the 2007 tag–recapture data (in particular the recaptures of 2006 releases in 2007); and (ii) the use of a tag–release selectivity. It noted that the tag data appeared to confirm concerns that the key uncertainty underlying the Ross Sea assessment model is the impact of movements and spatial structure in the *D. mawsoni* population, including the level and nature of the bias from non-homogeneous mixing assumptions of tagged fish.

4.13 The Working Group discussed the TSVPA assessment for *D. mawsoni* in the Ross Sea (WG-SAM-07/9). It noted the concerns raised in paragraph 3.8, and agreed that the model was not currently well enough advanced to provide assessment advice.

4.14 The Working Group recommended that the CASAL model continue to be used to provide the assessment advice for *D. mawsoni* in Subareas 88.1 and 88.2, with the changes identified in paragraph 4.10.

4.15 The Working Group discussed research priorities for the Ross Sea *D. mawsoni* assessment in the medium term. It agreed that:

(i) plausible spatial movement models need to be developed in order to address concerns of the level and nature of the bias that could result from non-homogeneous mixing assumptions of tagged fish;

(ii) methods need to be developed that would allow the evaluation of the sensitivity of the assessments to the inclusion of data of varying quality.

4.16 The Working Group noted that the quality of data arising from different vessels can be quite variable. In the same way that CPUE data needs to be standardised to overcome such variation, a procedure needs to be developed for standardising data from different vessels used in assessments, including data arising from observer programs. It recommended that WG-FSA and the Scientific Committee consider procedures necessary to ensure the provision of consistent high-quality data for assessments in multi-vessel, multi-nation fisheries.

Subareas 58.6/58.7 (Prince Edward and Marion Islands)

4.17 No new assessments were presented to WG-SAM. It is proposed to update the ASPM assessment presented to WG-FSA in 2006 so as to include the most recent data available, and to submit this update to WG-FSA-07. There will be no methodological changes to the assessment of toothfish in Subareas 58.6/58.7.

Division 58.5.1

4.18 WG-SAM recalled the progress made at the last meeting of WG-FSA in developing a fishery report for the fishery for *D. eleginoides* in the French EEZ in Division 58.5.1 (SC-CAMLR-XXV, Annex 5, paragraphs 5.86 to 5.90). A significant amount of fishery and observer data from this fishery had been submitted to the Secretariat, and WG-SAM encouraged France to continue submitting such data to CCAMLR, including the sampling design, data and results from the latest survey of Division 58.5.1.

4.19 WG-SAM encouraged exploration and efforts towards the development of an integrated assessment of *D. eleginoides* in Division 58.5.1 and continued contribution by French scientists to the work of WG-FSA.

EVALUATION OF MANAGEMENT STRATEGIES

Dissostichus spp.

5.1 Dr Ball presented WG-SAM-07/13 describing the work on developing methods for an assessment strategy evaluation (ASE) as a first step towards an MSE. The Working Group thanked Dr Ball for his presentation and noted that considerable progress has been made towards an ASE framework for the fishery for *D. eleginoides* in Division 58.5.2.

5.2 The Working Group noted that the framework described for ASE should provide a suitable basis for investigating a wide range of management strategies, and would allow investigation of sources of potential bias and error in assessments, for example assumptions of homogeneous mixing of tags, functional form of selectivities etc.

5.3 The Working Group suggested that methods to mimic past actions (including catch removals, tag releases and assessment strategies) are an important part of a simulation model, and encouraged the refinement of such methods within Fish Heaven.

5.4 The Working Group noted that there might be some utility in developing methods to allow estimation of parameters within a spatial simulation environment by fitting to fishery observations, for example, methods that allow estimation of movement rates from the observed length–age frequencies in the catch and observed tag movements.

5.5 Dr Brandão presented WG-SAM-07/10. The management procedure (MP) described adjusts the catch limit according to control decisions based on changes in CPUE trend and mean length of the catch. This MP has been evaluated using alternative operating models: 'Basecase', 'Optimistic', 'Intermediate' and 'Pessimistic', that reflect different current status

of the stock. Dr Hanchet noted that this MP might not be precautionary if a drop in mean length accompanied with an increase in CPUE which, given the control rules, results in an increase in the catch limit even when the increase in CPUE might not be indicative of a greater exploitable biomass. Dr Brandão indicated that the MP suggested is only one of a number of MPs to be explored, and further robustness tests will be applied in order to avoid such false signals. Dr Hanchet also suggested that potential changes in fishing depth should be incorporated in an operating model, since this would potentially affect mean length. Dr Brandão responded that this would be considered, but also suggested that checks outside the MP could be carried out that would show such changes in the fishery, which would trigger a re-evaluation of the MP. Further refinements in the use and evaluation of MPs are planned to be submitted to this Working Group in 2008.

Champsocephalus gunnari

5.6 WG-SAM encouraged Members to develop management strategies suitable for use in the fisheries for *C. gunnari* (see SC-CAMLR-XX, Annex 5, Appendix D). While it was recognised that such strategies may have some elements in common with the strategies being developed for *Dissostichus* spp., strategies for *C. gunnari* would need to take account of the species' short lifespan and highly variable natural mortality and recruitment.

Euphausia superba

5.7 The Working Group noted that the Scientific Committee had requested further consideration and development of approaches to subdivide the catch limit for krill in Area 48 among SSMUs. The Working Group recalled the work of WG-EMM on the development of models to assist with this task, notably through three workshops since 2004:

(i) Siena, Italy (2004 meeting of WG-EMM and the Workshop on Plausible Ecosystem Models for Testing Approaches to Krill Management) – A broad range of structures and functional relationships were discussed at these meetings, and it was generally apparent that it would be important to explore a variety of model structures that capture the potentially important direct and indirect effects of fishing (SC-CAMLR-XXIII, Annex 4, Appendix D, paragraph 3.16). With regard to developing models to provide advice on the subdivision of the precautionary krill catch limit, it was ultimately agreed (SC-CAMLR-XXIII, Annex 4, Appendix D, paragraph 7.6) that initial exploration of management options could be achieved using spatially structured krill population models that allow exploration of the interaction between:

(a) the krill population
(b) spatial catch limits and the fishery
(c) krill predators
(d) transport of krill.

(ii) Yokohama, Japan (2005 meeting of WG-EMM and the Workshop on Management Procedures) – Discussions at these meetings were less broad than those in Siena and focused primarily on the first version of KPFM. A number of suggestions were made to include other structural features in KPFM (e.g. predator survival that is dependent on foraging success, predators that can distribute foraging effort, and skewed competition). Ultimately it was agreed that at least three key aspects should be implemented in models for advising on the subdivision of the precautionary krill catch limit:

(a) incorporation of shorter time steps and/or seasonality
(b) incorporation of alternative movement hypotheses
(c) incorporation of a threshold krill density below which a fishery will not operate.

These minimum requirements were endorsed by the Scientific Committee (SC-CAMLR-XXIV, paragraph 3.20).

(iii) Walvis Bay, Namibia (2006 meeting of WG-EMM and the Second Workshop on Management Procedures) – Discussions at these meetings revolved around three models: EPOC, KPFM2 and SMOM. Additional minimum requirements were not specified at these meetings, but new suggestions for structural features did emerge (e.g. metapopulation dynamics for krill and models for fleet dynamics).

5.8 The Working Group also noted a recent workshop by Lenfest Ocean Program on 'Identifying and Resolving Key Uncertainties in Management Models for Krill Fisheries', held in Santa Cruz, California, USA, for which a summary letter of outcomes was provided by the conveners of that workshop to the Chair of the Scientific Committee who passed it to WG-SAM for consideration (WG-SAM-07/15).

5.9 The Working Group noted the positive conclusions of the Scientific Committee to significant progress in developing models and approaches to providing advice (SC-CAMLR-XXIV, paragraph 3.25; SC-CAMLR-XXV, paragraphs 3.8 to 3.15) and the recognition by the Commission that advice could be provided soon (CCAMLR-XXIV, paragraph 4.8; CCAMLR-XXV, paragraphs 4.8 to 4.11). It therefore agreed that it was important to progress this work rather than spending too much time discussing past issues. The Working Group reviewed the body of work to date, including further developments in models (WG-SAM-07/12, 07/14), to identify a program of work that could lead to staged advice on a subdivision of the krill catch among SSMUs at the 2008 meeting of WG-EMM.

5.10 The Working Group agreed that such advice and its implementation needed to occur in a staged approach towards subdividing the krill catch among SSMUs, taking account of the requirements of predators. Such an approach would involve, at each stage, an evaluation of the risks to krill, predators and the fisheries of the different options for subdividing the catch given the uncertainties in model structures, our understanding of the dynamics of the krill-based ecosystem and the future interactions of the fishery with the system. Such risks would be evaluated for different levels of maximum aggregate catch across SSMUs. Thus, advice at each stage would be on the strategy for subdividing catch along with the attendant risks at different aggregate catches. This approach will provide the Commission with the best scientific information and advice for subdividing the krill catch at any given time.

5.11 The Working Group agreed that advice for the first stage in this development could be given next year on the basis of the following discussion.

Options for subdividing the catch limit

5.12 The Working Group recalled previous discussions on the options to subdivide the krill catch among SSMUs (SC-CAMLR-XXV, Annex 4, Appendix D, paragraph 1.4), including:

(1) the spatial distribution of catches by the krill fishery;

(2) the spatial distribution of predator demand;

(3) the spatial distribution of krill biomass;

(4) the spatial distribution of krill biomass minus predator demand;

(5) spatially explicit indices of krill availability that may be monitored or estimated on a regular basis;

(6) pulse-fishing strategies in which catches are rotated within and between SSMUs.

5.13 WG-SAM-07/14 outlined how Option 6 could provide for a 'structured fishing' approach as the fishery develops in order to acquire data that could be used to help parameterise models, distinguish between competing hypotheses about how the ecosystem works and to better understand the effect of fishing on krill predators. Dr Constable elaborated this approach in his presentation to the meeting, noting that the design of a structured fishing program could be:

(i) during the development of the fishery, catches would be allocated among SSMUs according to the option for subdivision considered most appropriate for a fully developed fishery, with the expectation that catches could be taken in an individual SSMU at that level;

(ii) some SSMUs are used as controls (closed during the period of the structured fishing) and chosen to enable assessment of large-scale krill movement between SSMUs (flux) as well as interannual variation and climate change trends in the absence of fishing;

(iii) monitoring of krill (abundance) and land-based predators (e.g. diet, reproductive success) would be needed at an appropriate level (across open and closed SSMUs) to identify the effects of fishing on those predators;

(iv) the assignment of open and closed areas may be rotated among SSMUs over time –

(a) to determine the effects in different locations and under different conditions; and/or

(b) to appropriately randomise the effects; as well as

(c) to enable focused study on particular process/management issues.

5.14 The Working Group agreed that this structured approach to fishing could be useful for providing feedback into the assessment process and management during the developmental phase.

5.15 In further consideration of these options, the Working Group noted that the maximum catch to be subdivided among SSMUs at present should only be the aggregate catches for Subareas 48.1, 48.2 and 48.3, i.e. 3.168 million tonnes of the 4 million tonnes allowed from Area 48 as a whole, as this is what is provided for those areas in Conservation Measure 51-01. There are currently no SSMUs identified for Subarea 48.4.

5.16 The Working Group noted that Stage 1 of a subdivision could be an initial subdivision based primarily on Options 2 to 4, noting that Option 1 was found to achieve the poorest balance of ecosystem and fishery objectives amongst the options considered at the 2006 workshop (SC-CAMLR-XXV, Annex 4, Appendix D). It also noted that development of approaches under Options 5 and 6 should be accorded a high priority starting in 2009, as the implementation of these approaches will help in the assessment processes in the future.

Use of empirical data in models

5.17 The Working Group agreed that data should be used to provide the foundation for the ecosystem models used in this work. Such data can be used to parameterise and/or initialise the models (inputs) in order to appropriately scale the behaviours in each model SSMU. Alternatively, time series of data can be used to estimate parameters of the models as inputs, or used to validate the models by comparing outputs from trials with either time series of abundances or quantitative attributes expected of the system, e.g. krill biomass variability.

5.18 In considering all aspects of data for use in the development of ecosystem models, the Working Group recognised that although Area 48 was probably the most intensively studied region in the Convention Area it was, by comparison to other marine systems, data-sparse. In recognising this, the Working Group agreed that advice should be sought on the best data available for initialising and validating models along with an appropriate evaluation of the uncertainties or qualities inherent in those data.

5.19 The Working Group considered that the newly formed WG-SAM needs to remain actively engaged with WG-EMM so that modellers continue to interact with data holders who understand the quality of data and parameters, the relationships between the data and the ecosystems from which they are derived, and who are likely to collect new data. The Working Group agreed to produce a focused and prioritised list of key data and model uncertainties and to pass this list to WG-EMM in order to receive advice on the process and likely time scale involved in providing new and/or refined parameter estimates.

5.20 In discussion of the need for a common dataset with which to initialise models, it was clear that different models will need to use different parameters in the initialisation process. Models might use empirically derived estimates of predator abundance and/or demand. Alternatively, these estimates may be derived using a model-based approach. The Working Group agreed that in both cases it was essential that values used were reconcilable with a

plausible representation of the state and operation of the ecosystem. For example, it is important to avoid a situation where a model provides outputs that appear plausible, while using initial values for some parameter values that are biologically implausible.

5.21 The Working Group agreed that a model should provide a sufficiently realistic representation of the ecosystem. This should be checked by testing the outputs of the model against existing data. The Working Group agreed to request advice from WG-EMM on a key (benchmark) set of attributes and data series that would be used to appropriately benchmark any ecosystem model of the southwest Atlantic sector of the Southern Ocean being used to examine the effects of krill fishing on dependent species in SSMUs. It was also agreed that a defensible justification is required if model inputs, structure or outputs do not meet an individual benchmark. The Working Group agreed that the parameter values in Hill et al. (2007) could provide the foundation for developing these benchmarks.

5.22 With respect to time series of key aspects of the system, such as krill density, predator population and reproductive performance, three levels of specification were suggested where the model reproduces:

- the general characteristics (i.e variance/distribution) of the time series
- specific aspects of the time series
- relative magnitude of changes represented by the time series.

5.23 It was agreed that an iterative process was required for assessing whether models sufficiently reflect these attributes. Agreement on an *a priori* set of benchmarks, whereby a model is considered sufficiently realistic for the provision of advice, should be a high priority in the short term.

5.24 On the basis of these discussions, the Working Group developed an initial list of potential benchmark datasets for consideration by WG-EMM. In this respect, the Working Group drafted a 'calendar' of known or suspected changes in the ecosystem that could provide a set of reference observations for validating and tuning models used to provide risk assessments about the effects of distributing krill catches among SSMUs during a staged development of the fishery in Area 48. This calendar covers the period 1970 to the present and is provided, by subarea and species group, in the list below. Reference observations highlighted with an asterisk were considered to be less certain and, therefore, likely to be of secondary importance in model validation and tuning.

(i) Subareas 48.1 and 48.2 –

(a) krill

- near-step change in total biomass and interannual variability in biomass in about 1986 (biomass was greater and less variable prior to the change point);

- interannual variability in biomass is concordant with that in Subarea 48.3;

(b) penguins

- increase in abundance of about 5–10% per year during 1970 to about 1977;
- overall decline in abundance of 60–70% during the period from about 1977 to 2000 (this decline should not be explained by changes in breeding success that are related to changes in food availability during the breeding season);
- *continued, possibly steeper, decline after 2000 (this decline may be explained by changes in breeding success that are related to predation on chicks and fledglings);

(c) seals

- increase in abundance of about 10–15% per year during 1970 to about 1995;
- no significant trend in abundance after about 1995;

(d) whales

- increase in abundance of about 4–5% per year since about 1980;

(ii) Subarea 48.3 –

(a) krill

- biomass was greater and less variable prior to about 1980 than after about 2000;
- *smoother (than in Subareas 48.1 and 48.2) change in biomass and interannual variability during the period from about 1980 to 2000;
- interannual variability in biomass is concordant with that in Subareas 48.1 and 48.2;

(b) penguins

- *possibly no significant trend in abundance from 1970 to about 1980;
- overall decline in abundance of 40–50% during the period from about 1980 to the present;

(c) seals

- increase in abundance of about 10–15% per year during the period from 1970 to about 1988;
- *possibly slower rate of increase in abundance after about 1988;

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* Reference observations considered to be less certain and, therefore, likely to be of secondary importance in model validation and tuning.

(d) whales

- increase in abundance of about 4–5% per year since about 1980.

5.25 The Working Group noted a number of points about the calendar outlined above. Firstly, rates and timings of changes are only approximate. Secondly, levels of abundance and variability are not provided. Finally, no reference observations are provided for fish.

5.26 The Working Group agreed that WG-EMM be requested to review and, as necessary, revise this calendar. Furthermore, WG-EMM was strongly encouraged to complete this process during its 2007 meeting, providing, if appropriate, a revised calendar in its report, noting that if this is not possible, the calendar provided above will serve as a default and modelling should proceed using it. It was also agreed that, for the purposes of the ensuing risk assessment, the calendar would be considered fixed after the 2007 meeting of the Scientific Committee.

5.27 The Working Group noted that models could be continually improved in terms of their realism. However, consistent with the advice from the Lenfest workshop (WG-SAM-07/15), it was noted that improved realism may not necessarily give rise to improved advice on this issue. Furthermore, a process that continually requests modifying models before advice is given could result in no advice being given. The Working Group agreed that model uncertainties can be included in a risk assessment and that the process defined here is likely to result in staged advice on subdividing the krill catch among SSMUs that can be considered the best scientific information available.

Models

5.28 Three models relevant to the evaluation of options for subdividing the precautionary krill catch limit in Area 48 among SSMUs were available to the Working Group. These models, and the relevant documents, were EPOC (WG-SAM-07/14), SMOM (WG-SAM-07/12) and KPFM2 (renamed FOOSA and described in papers presented to WG-EMM in previous years – WG-EMM-06/22). The Working Group summarised the current state of model structure and functionality as follows:

(i) the minimum requirements specified in SC-CAMLR-XXIV, paragraph 3.20, have been achieved within FOOSA and SMOM;

(ii) many structural features have been added to the existing models but, to date, this additional functionality has not been fully explored;

(iii) additional structural features could be developed, but it is not clear whether these are necessary in the short term.

5.29 With specific regard to the last point in this list, the Working Group recalled the guidance that the conveners of the Lenfest workshop provided to the Chair of the Scientific Committee (WG-SAM-07/15) that recognised 'that not every feature of the krill–predator–fishery system needs to be captured' in models that may be used to provide management advice.

5.30 A summary was presented by Dr Plagányi of a recent FAO workshop on 'Modelling Ecosystem Interactions for Informing an Ecosystem Approach to Fisheries: Best Practices in Ecosystem Modelling', held in Tivoli, Italy, in July 2007. The summary focused on the key attributes to be considered in ecosystem model development together with the current best practice for handling each of these. This provided some useful guidelines for modelling and a means of evaluating the CCAMLR models being developed against the best practices. It was noted that there is a continuum in ecosystem model applications ranging from: (i) basic understanding that provides an underlying context but is not used explicitly in decision-making; (ii) strategic decisions that are fairly long term and broad based and linked to policy goals; to (iii) short-term tactical decisions that typically take the form of a precise quantitative set of instructions based on data and assessments. It was also noted that most ecosystem models considered at the workshop are strategic but not tactical.

5.31 A summary of the models developed for WG-EMM and updates were provided by the model authors to the meeting.

5.32 The krill–predator–fishery model (FOOSA) was presented by Dr Watters. The model has not been changed since the last meeting of WG-EMM, and the most up-to-date documentation for the model is contained in WG-EMM-06/22. The presentation was therefore brief, highlighting structural aspects that may be new to WG-SAM participants. FOOSA is structured with both a generic time step (that includes seasonality) and a generic spatial structure (that can resolve SSMUs). The population dynamics of krill and predators (up to four predators per SSMU) are described by delay-difference models that account for changes in abundance. The parameterisation of these delay-difference equations is sufficiently flexible to allow for the exploration of a wide range of hypotheses regarding the structure and function of the ecosystem. For example, alternative movement rates for krill, functional responses for predators (e.g. Holling Type II or Type III responses), predator–prey interaction terms (e.g. the degree to which predator breeding is influenced by per-capita consumption of krill), competition coefficients among predators and the fishery (e.g. whether predators or the fishery are better able to capture krill when krill are a limiting factor), and stock-recruitment relationship for predators and krill can all be specified. Process error is added to this relationship, and FOOSA uses Monte Carlo simulations to quantify uncertainty. FOOSA produces a large suite of performance measures and graphical output.

5.33 Dr Plagányi presented SMOM, which was first presented at WG-EMM-06. Updates to SMOM are described in WG-SAM-07/12. SMOM has been updated to explicitly model four generic predators (penguin, seal, fish, whale) and has addressed the recommendation to include a shorter time step/seasonality. An option for modelling movement in an analogous manner to that used by FOOSA has also been included in the model. Uncertainty in the values of the parameters leads to the production of an 'envelope' of future states that are considered likely to bound the true state, and it was highlighted how data could be used to narrow the range of uncertainty in outputs. An example was provided of how an MSE approach using a subdivision control rule could be used to manage the allocation of krill catch in Area 48 among SSMUs.

5.34 Dr Constable presented the EPOC modelling framework, which was first presented at WG-EMM-05. WG-SAM-07/14 described the latest version of the EPOC framework. EPOC is based around a highly flexible framework written in the R statistical language. The model is made up of a central controller, which integrates separate modules on the biota, environment, and human/management activities. Each component may be described at a level

of spatial, temporal and structural complexity deemed appropriate. EPOC then combines the elements in these modules to model the spatially explicit dynamics of the system. The set of templates for elements has been updated in order to configure EPOC to evaluate the different options for subdividing the krill catch including Options 5 and 6. These templates now include complex options for representing, as required, the primary production, krill, predator and fishery system of the southwest Atlantic.

5.35 The Working Group noted the past and present developments in models to evaluate the SSMU options. It agreed that FOOSA and SMOM were sufficiently advanced to undertake the work required to lead to advice for a first stage in the implementation of a subdivision strategy. Although not as advanced as FOOSA or SMOM, EPOC was noted to have been advanced to have the potential to explore the options for subdividing the krill catch among SSMUs. The Working Group agreed that the process outlined below for developing advice next year should not preclude the development of new models, provided that the development and use of such models satisfactorily participated in the process below.

5.36 The Working Group noted that catch limits are managed in the model as a harvest rate, γ, of a model estimate of biomass. This means that the overall catch limit of 4 million tonnes would be modelled as $1.0 \cdot \gamma \cdot$ [estimate of biomass]. The proportion of γ that would be consistent with the trigger level of 620 000 tonnes would be about 0.15. Similarly, the proportion of γ that would be consistent with the aggregate catch in Subareas 48.1, 48.2 and 48.3 of 3.168 million tonnes would be about 0.8.

Stage 1 scenarios

5.37 The Working Group agreed that the following constituted an essential set of model scenarios when evaluating the different SSMU options:

(i) the initial conditions set in the model need to be defensible, ideally by using available data;

(ii) the baseline model period needs to be consistent with management strategy or simulation requirements;

(iii) simulations should include a 20-year period with fishing followed by a 20-year recovery period with no fishing. This is considered adequate for the staged approach, but one of the questions that remain outstanding is how long this period should be to fully capture potential declines and recovery of long-lived species;

(iv) model outputs during the next stage should focus on comparing SSMU Options 2, 3 and 4;

(v) simulations should be run for the following levels of harvest rate (here expressed as fractions of γ): 0.0, 0.15, 0.25, 0.5, 0.75, 1.0 so as to provide advice on the risks, given the attendant model and ecosystem uncertainties of the aggregate catches and subdivision strategy causing problems for krill, predators or the fishery at different stages in the development of the fishery;

(vi) the role of flux in krill dynamics needs to be considered, with alternative representations shown, such as scenarios with flux bounded by the seasonal movement matrices based on OCCAM output and no movement;

(vii) a range of interaction functions should be investigated to represent uncertainty in the relationship between krill availability and predator population responses;

(viii) the following scenarios are considered desirable but optional:

(a) scenarios capturing the uncertainty in predator survival rate estimates
(b) scenarios including climate change effects
(c) consideration of fleet dynamics (depending on flexibility within options).

5.38 Model validation, as described above, and evaluation of the performance of different scenarios (see below) could be undertaken by either comparing model outputs from trials with no fishing or using a model history phase prior to fishing.

Performance measures

5.39 The ecosystem models were developed to compare, through simulation, the performance of candidate options for allocating the precautionary krill catch limit in Area 48 among SSMUs, where relative performance is judged according to how well they meet the objectives of Article II of CCAMLR. Performance measures are derived from the status of krill, predator populations and the fishery over relevant time scales.

5.40 Performance of the krill population has been defined according to the decision rules of the precautionary approach for calculating yield of krill, where the objectives for the krill stock are given in operational terms (SC-CAMLR-XXIV, Annex 4, Appendix D, paragraph 4.1):

(i) the probability of krill spawning stock falling below 20% of the median pre-exploitation spawning stock abundance is less than or equal to 0.1;

(ii) the median escapement of the spawning stock after 20 years is 0.75 of the median pre-exploitation spawning biomass.

5.41 Article II states the requirement that fishery impacts on species that are dependent on, or related to, harvested species should be 'potentially reversible' within two to three decades of the cessation of fishing. The Working Group noted that the concept of 'reversible' will need more theoretical work to suggest operational definitions and, thereby, be able to test the performance of options against this criterion.

5.42 The Working Group recalled considerations in the past of performance measures for predators (SC-CAMLR-XXIV, Annex 4, Appendix D, paragraphs 4.2 and 4.3) and at the recent Lenfest workshop (WG-SAM-07/15) and that there are two main types of such measures: (i) assessment of the conservation status of local populations based on rates of decline and recovery that are scaled to generation times, and (ii) status of populations relative to some historical level or a benchmark level. The latter include a probability of being above or below such levels rather than specific states.

5.43 The above performance measures for krill and predators consider population status relative to its status before the onset of fishing. As indicated above, it might be useful to consider the status of predator populations relative to that expected in the absence of fishing in order to account for trends in the ecosystem that are not a result of fishing.

5.44 Performance measures for the fishery can include global and local (SSMU) aggregate catches over the period of fishing, deviations from allocated catch and the variability in catches and catch rates. Other measures might include how often fishing vessels may need to move between SSMUs in order to maintain catch rates.

5.45 The Working Group noted that the code for FOOSA includes methods for calculating 50 performance measures related to the quantities described here.

5.46 In 2006, WG-EMM considered that some form of aggregation of performance measures is desirable in order to convey complex results. Such aggregate performance measures should, *inter alia*: (i) take into account, and appropriately combine, all model outputs considered to be valuable; (ii) take into account correlations between various measures; (iii) provide sufficient information to enable performance to be assessed relative to Article II; (iv) aim to be value-free (e.g. 'high versus low' rather than 'good versus bad' or 'acceptable versus not acceptable') (SC-CAMLR-XXV, Annex 4, Appendix D, paragraphs 2.12, 4.4 and 4.5).

5.47 The Working Group noted that care needs to be taken in developing aggregate performance measures because they will be sensitive to the choice of measures in the aggregate, the weighting applied to each and the method of aggregation. The Working Group noted that a consistent form for presenting performance measures and the trade-offs between different SSMU options needs to be decided by WG-EMM, noting the substantial progress at previous meetings.

Risk assessment of Stage 1 scenarios

5.48 The Working Group agreed that the provision of advice next year could be based on a risk assessment using elements of the performance measures but noting that some performance measures will be most useful in the subsequent stages of the development of management strategies for krill. It was agreed that the following elements will be considered in a risk assessment:

(i) Suitable fishery performance measures could be selected from those currently used by FOOSA or could be model specific, provided they represented long-term performance and variability. It was agreed that fishery performance would no longer be evaluated relative to the historical fishing distribution (Fishing Option 1).

(ii) Suitable predator performance measures should be shown:

- relative to benchmark levels of both the pre-exploitation state and relative to comparable no-fishing trials;

- for two times in the simulation periods (the end of the fishing period and the end of the recovery period);

- together with an indication of the impact and likelihood of risk, by reflecting the probability of change in the populations at the two times and at the following levels relative to the benchmark levels: ≥1.0, 0.75, 0.5, 0.25.

(iii) Performance measures for krill should be based on the existing decision rules.

(iv) A risk matrix of the performance of different options relative to these measures should be presented.

Process for providing advice on Stage 1

5.49 The Working Group recognised that to make progress towards developing management advice to allocate krill catch limits to SSMUs during 2008, it would be necessary to follow an agreed intersessional plan. The plan would include the development and use of benchmark scenarios and data as discussed above that could be investigated in all viable models, so that comparisons could be made by the Working Group and advice provided to WG-EMM. It was recognised that models vary in structure and form, so it will be necessary during the coming intersessional period to identify a basic set of benchmark specifications to be used by the Working Group to verify the appropriateness of models for use in this work.

5.50 Intersessionally model developers should distribute, via the newsgroup, results of model validation and verification using agreed datasets, following review by WG-EMM at its 2007 meeting and subsequently archived at the Secretariat. The Working Group had reviewed results from FOOSA and SMOM and was aware of the continued development of an ecosystem model in EPOC. These are candidate models for this process. This intersessional process will also aim to identify important issues to be considered and their relative impacts on the risk assessment.

5.51 The Working Group agreed to review the available submission of models and results to provide a technical commentary to WG-EMM on the adequacy of the models and approaches for use in the risk assessment. It would then be expected that WG-EMM will be able to comment on the realism of the models and results and to complete the risk assessment in order to provide advice to the Scientific Committee on a subdivision of the krill catch limit among SSMUs and the implementation risks for different catch levels. It is envisaged that the Commission should be able to subdivide the krill catch limit among SSMUs next year and set a threshold catch level below which the subdivision should not pose substantial risks to krill, predators and the fishery. In the absence of such advice, the Working Group agreed that there was no basis at present on which to judge that the 620 000 tonne trigger level does not pose a risk to predators.

FUTURE WORK

6.1 This first meeting of WG-SAM was a transition meeting, focusing on the tasks of WG-FSA as well as on the methods for subdividing the krill catch limit among SSMUs (SC-CAMLR-XXV, paragraph 13.12). The Working Group aims to provide technical advice to the Scientific Committee and its working groups based on an agenda developed by all the conveners of working groups and the Chair of the Scientific Committee (SC-CAMLR-XXV, paragraph 13.13).

Terms of reference

6.2 During the intersessional period, the conveners of the working groups, the Chair of the Scientific Committee and the Secretariat consulted as to the terms of reference and name of this Working Group (SC CIRC 06/47). The Working Group agreed that the name 'Working Group on Statistics, Assessments and Modelling' is appropriate. It also agreed that the following terms of reference could be used to define the work of this group:

To provide advice to the Scientific Committee and its working groups on:

(i) quantitative assessment methods, statistical procedures and modelling approaches for the conservation of Antarctic marine living resources;

(ii) the implementation and data requirements of such methods, procedures and approaches.

6.3 The Working Group noted that one of its roles was to provide expert review of methods and procedures that leads to advice, such as estimates of yield, to the Scientific Committee. It agreed that not all methods, procedures and approaches would need to be reviewed by WG-SAM. The Working Group agreed that where a working group is not able to judge the utility or the implementation of a method, procedure or approach, the following process should be followed:

(i) the method, procedure or approach be submitted to WG-SAM with sufficient information to enable replication of the model. This includes, but is not limited to, the software package or code and the input data;

(ii) the method, procedure or approach be tested against previously documented and appropriate scenarios, simulated data or other ecological models;

(iii) the realism and suitability of the method, procedure or approach be reviewed by the relevant working group (WG-EMM, WG-FSA or ad hoc WG-IMAF).

6.4 The Working Group also noted that there should be no undue delay in the process as a result of the above requirements.

6.5 In applying this process, the Working Group noted that the process of verifying that computer programs and the underlying models operate as intended need not involve detailed examination of the program code, but would require adequate testing of the programs against appropriate datasets or scenarios or by comparison with the results of other programs and/or

models. It was also noted that the degree to which outputs of such models had to match such data or scenarios would be dependent on the application intended for the models. The Working Group agreed that the importance of testing methods, procedures and approaches is to assure the Working Group that they work as intended and that no errors are evident in the operation of the program that could impact on results required by the Scientific Committee and its working groups.

Long-term work plan

6.6 The Working Group agreed it should have a long-term work program while maintaining sufficient flexibility to address topical issues. It was noted that the priorities for long-term work are to evaluate management strategies for *Dissostichus* spp. and krill, and these topics will require substantial work over the next few years. Other topics requiring attention include the development of spatially structured assessment models and of assessment models for by-catch species (e.g. rajids). Flexibility can be maintained by allowing for a relatively open agenda that is annually agreed by the conveners of all working groups and subject to review and agreement by the Scientific Committee. Along these lines, the Working Group recalled paragraph 13.13 of SC-CAMLR-XXV, which calls on the conveners to jointly submit papers indicating forthcoming priorities for WG-SAM at annual meetings of the Scientific Committee.

6.7 In developing annual agendas for WG-SAM, the Co-conveners were requested to consider structuring them around topics (e.g. the evaluation and use of observer data) rather than structuring them around species and statistical areas (as was the case this year).

6.8 It was further advised that time should be provided to:

(i) continue the priority work items necessary to support each working group (e.g. the review of assessment models and the evaluation of management strategies);

(ii) allow for review and discussion of new papers that might be submitted to WG-SAM;

(iii) allow for focused discussion on one or two technical issues that are identified in advance and that are common to all working groups.

This type of time budget would likely provide both continuity and adaptability.

6.9 Discussions on common technical issues will facilitate increased dialogue between participants who normally focus their attention on particular topics (e.g. single-species stock assessments versus ecosystem modelling). These discussions can be motivated by scoping papers that are submitted by and through individual working groups to the joint group of conveners. Such scoping papers should identify the topic nominated for technical discussion, provide reasons why the topic is relevant and important, and suggest how a technical discussion might proceed to successful conclusion. The conveners could set up a rotating list of such scoping papers, selecting items from the list as time allows and when they are particularly relevant.

6.10 Ultimately, it was acknowledged that WG-SAM, as will all the other working groups, will likely be responsible for completing a large volume of work in a limited amount of time. The workload will have to be managed by carefully considering short- and long-term priorities and flexibly adjusting the annual agenda. It will be important for the Scientific Committee to provide clear guidance on its priorities.

Other issues

Assessments at multi-year intervals

6.11 The Working Group discussed a request from the Scientific Committee to provide advice on conducting assessments at multi-year intervals (SC-CAMLR-XXV, paragraphs 4.55 to 4.59).

6.12 The Working Group agreed that multi-year intervals between assessments should be considered in the sense of a trade-off between the risk of gross errors in an assessment, and the considerable saving of time both in the working groups and intersessionally. Such savings would provide time to address other high-priority issues, such as evaluations of the efficacy of assessments and MSEs for achieving the objectives of the Convention.

6.13 Mr Dunn presented work undertaken in the meeting that evaluated the additional risk to the stock of an over-catch in one year, i.e. simulating a year that did not have an assessment, but for which there should have been a downward adjustment to the catch, using the 2006 base-case assessment models for the Ross Sea (Subareas 88.1 and 88.2) and South Georgia (Subarea 48.3) *Dissostichus* spp. fisheries. The results for trials of an over-catch of two- and three-times the estimated yields for one and two years in a row showed only a small increase in the risk (0.5–1.0%). However, in the model, the catch limit is not reassessed and returns to the level set at the beginning of the projection period. In reality, the increased risk would not be sustained, as the reassessment after the period of over-catch would result in a reduced catch limit, and reduce the additional risk to near zero.

6.14 The Working Group noted that the need for annual assessments would need to be decided by WG-FSA for each fishery, and that trials such as those described above could be undertaken for new model scenarios or species to evaluate the risks of different frequencies of assessments.

6.15 The Working Group noted that the frequency of assessments should be considered part of the management strategy and could be evaluated within an MSE framework.

6.16 The Working Group noted that an MSE approach also provides an opportunity for considering how to use signals of stock stress to trigger assessment updates, such as using changes in size or age distributions of catch, rates of catch and rates of recapture of tagged fish. Exploration of suitable indicators from the data inputs in an MSE would ensure the robustness of such trigger points.

6.17 The Working Group noted the general guidelines provided by CCAMLR-XXV (paragraph 4.51) that WG-FSA retain the option to undertake an assessment in any given year if new or refined methods of assessment become available or parameters used in the assessment are revised significantly.

6.18 On the basis of the simulated results and ensuing discussions, the Working Group agreed that, where a toothfish stock is at or above target levels and where assessments have been stable, assessments of toothfish could be performed on a biennial cycle without incurring significant additional risk. The Working Group encouraged further work to evaluate the risks and determine robust indicators to trigger assessment updates.

OTHER BUSINESS

7.1 WG-SAM noted that the authors of two of the meeting documents had indicated that they wished their papers to be considered for publication in *CCAMLR Science*. Both of these papers had been discussed adequately during the meeting, and WG-SAM had no further advice and feedback to the authors or the Editorial Board.

GENERAL ADVICE

Advice to WG-EMM

8.1 The Working Group indicated that an integrated assessment of krill could be progressed with:

(i) the assembly of data from different krill survey time series to try and estimate movement rates (paragraph 3.12(iii)(b));

(ii) the collection of high-quality biological data from all commercial vessels (paragraph 3.13(ii)).

8.2 The Working Group identified a program of work that could lead to advice on a subdivision of the krill catch limit among SSMUs at the 2008 meeting of WG-EMM (paragraphs 5.49 to 5.51) and recommended that a staged development of the fishery be adopted (paragraph 5.24).

8.3 The Working Group agreed to request advice from WG-EMM on a key (benchmark) set of attributes and data series (calendar) that would be used to appropriately benchmark any ecosystem model of the southwest Atlantic sector of the Southern Ocean being used to examine the effects of krill fishing on dependent species (paragraphs 5.21 to 5.24).

8.4 The Working Group agreed that WG-EMM be requested to review and, as necessary, revise the calendar in paragraph 5.24. Furthermore, WG-EMM was strongly encouraged to complete this process during its 2007 meeting, providing, if appropriate, a revised calendar in its report, noting that if this is not possible, the calendar will serve as a default and modelling should proceed using it. It was also agreed that, for the purposes of the ensuing risk assessment, the calendar would be considered fixed after the 2007 meeting of the Scientific Committee (paragraph 5.26).

8.5 The Working Group noted that the development of aggregate performance measures is an important issue for WG-EMM. It also noted that a consistent form for presenting

performance measures and the trade-offs between different SSMU options needs to be decided on by WG-EMM, noting the substantial progress at previous meetings (paragraphs 5.46 and 5.47).

8.6 The Working Group developed a process that will lead to advice on a subdivision of the krill catch limit among SSMUs in 2008 and requested that WG-EMM endorse and participate in this process (paragraphs 5.49 to 5.51).

Advice to WG-FSA

8.7 The Working Group recommended that Members provide the following contributions to the next WG-FSA meeting:

(i) a descriptive analysis of the tagging program in Division 58.5.1, and updates of descriptive analyses of tagging programs in Division 58.5.2 and Subarea 48.3 (paragraph 2.2), including an update on the method for triple tagging of fish in the Division 58.5.2 fishery using PIT tags to assist in evaluating external tag observation and shedding rates (paragraph 2.7);

(ii) an updated assessment for *D. eleginoides* in Division 58.5.2, based on the model framework provided at WG-FSA-06 and including the 2006/07 survey and fishery data (paragraph 4.9);

(iii) an update of the ASPM assessment for *D. eleginoides* in Subareas 58.6/58.7, as presented to WG-FSA-06, to include the most recent available data (paragraph 4.17);

(iv) the development of an integrated assessment of *D. eleginoides* in Division 58.5.1 (paragraph 4.19);

(v) the development of management strategies suitable for use in the fisheries for *C. gunnari* (paragraph 5.6).

8.8 The Working Group noted that the Secretariat would take responsibility for coordinating tagging programs in new and exploratory fisheries starting from the 2007/08 season. It recommended that WG-FSA consider the development of advice on how it should manage the collection of non-toothfish tagging data, particularly from voluntary tagging programs (paragraph 2.6).

8.9 The Working Group recommended several improvements in rajid data collection methods and that survivorship experiments for different species, a wider range of depths and with longer holding periods, be undertaken (paragraph 3.18).

8.10 The Working Group identified several issues related to species identification, catch sampling (the trade-off between sampling rajids for length and sex versus cutting them off the lines), improving estimates of age and growth, improving tagging protocols, and additional survivorship experiments, which would improve data relative to by-catch species, but would also affect the workload of scientific observers. The Working Group acknowledged the heavy workload of scientific observers and considered that the priorities for by-catch species may be

better met by focusing each year on a particular species group. So that, for example, 2008/09 could be the Year of the Rajid, and 2009/10 could be the Year of the Macrourid. The Working Group endorsed the need for further work in each of the areas identified by WG-SAM-07/4 and recommended that these issues be further addressed by WG-FSA (paragraph 3.20).

8.11 The Working Group recommended that for toothfish in Division 58.5.2:

- the assessment is likely to be improved through inclusion of ageing data, which would enable better estimation of recruitment and selectivity within the CASAL framework (paragraph 4.7);

- the assessment model needs further development, including further investigation of the sensitivity of the model to assumptions and constraints (paragraph 4.8).

8.12 On the basis of the simulated results and ensuing discussions, the Working Group agreed that, where a toothfish stock is at or above target levels and where assessments have been stable, assessments of toothfish could be performed on a biennial cycle without incurring significant additional risk. The Working Group encouraged further work to evaluate the risks and determine robust indicators to trigger assessment updates (paragraph 6.18).

8.13 The Working Group agreed that a Leslie-DeLury depletion analysis could be considered in providing advice on potential yields in exploratory toothfish fisheries, depending on broader consideration of the application of CCAMLR's precautionary approach in those fisheries (paragraph 3.4).

8.14 The Working Group recommended that the CASAL model continue to be used to provide the assessment advice for *D. mawsoni* in Subareas 88.1 and 88.2, with the changes identified in paragraph 4.10 (paragraph 4.14).

8.15 The Working Group recommended that WG-FSA and the Scientific Committee consider procedures necessary to ensure the provision of consistent high-quality data for assessments in multi-vessel, multi-nation fisheries (paragraph 4.16).

Advice to ad hoc WG-IMAF

8.16 WG-SAM did not consider any matter directly related to the work of ad hoc WG-IMAF during its first meeting. However, the Working Group wished to communicate its terms of reference and general approach to WG-IMAF (see paragraphs 8.18 and 8.19), and looked forward to collaborating on matters of interest to both working groups.

Future work of WG-SAM

8.17 The Working Group agreed to medium-term research priorities for toothfish assessments (paragraphs 4.15(i) and (ii)):

(i) plausible spatial movement models need to be developed in order to address concerns about the level and nature of the bias that could result from non-homogeneous mixing assumptions of tagged fish;

(ii) methods need to be developed that would allow the evaluation of the sensitivity of the assessments to the inclusion of data of varying quality.

Scientific Committee

8.18 During the intersessional period, the conveners of the working groups, the Chair of the Scientific Committee and the Secretariat consulted as to the terms of reference and name of this Working Group (SC CIRC 06/47) (paragraph 6.2). The Working Group agreed that the name 'Working Group on Statistics, Assessments and Modelling' is appropriate. It also agreed that the following terms of reference could be used to define the work of this group:

To provide advice to the Scientific Committee and its working groups on:

(i) quantitative assessment methods, statistical procedures, and modelling approaches for the conservation of Antarctic marine living resources; and

(ii) the implementation and data requirements of such methods, procedures and approaches.

8.19 The Working Group noted that one of its roles was to provide expert review of methods and procedures that leads to advice, such as estimates of yield, to the Scientific Committee. It agreed that not all methods, procedures and approaches would need to be reviewed by WG-SAM. The Working Group agreed that where a working group is not able to judge the utility or the implementation of a method, procedure or approach, the following process should be followed (paragraph 6.3):

(i) the method, procedure or approach be submitted to WG-SAM with sufficient information to enable replication of the model. This includes, but is not limited to, the software package or code and the input data;

(ii) the method, procedure or approach be tested against previously documented and appropriate scenarios, simulated data or other ecological models;

(iii) the realism and suitability of the method, procedure or approach be reviewed by the relevant working group (WG-EMM, WG-FSA or ad hoc WG-IMAF).

8.20 The Working Group noted that KPFM2 has been renamed FOOSA (paragraph 5.28).

8.21 The Working Group requested the Scientific Committee consider the proposed approach for structuring the future work program for WG-SAM in paragraphs 6.6 to 6.10.

8.22 The Working Group recommended that multi-year intervals between assessments is tractable as a reasonable trade-off between the risk of gross errors in an assessment and the management of workloads for other high-priority issues, noting the special consideration of this issue in paragraphs 6.12 to 6.18.

ADOPTION OF REPORT AND CLOSE OF MEETING

9.1 The report of the meeting was adopted.

9.2 Drs Jones and Constable thanked all participants and contributors to the work of WG-SAM for a very successful first meeting. They also thanked the New Zealand hosts for their warm hospitality, and the Secretariat for its support.

9.3 On behalf of the Working Group, Dr Holt thanked the Co-conveners for their excellent work in preparing for, and running of, the meeting. He also thanked Dr Jones for his previous role as Convener of WG-FSA-SAM which had paved the way to WG-SAM. The first meeting of WG-SAM had established the Working Group's role in the work of the Scientific Committee and its working groups, and had resulted in further advances in the assessment and management of fisheries for toothfish and krill.

9.4 WG-SAM looked forward to future work under the leadership of Dr Constable, and wished Dr Jones success in his forthcoming role as Convener of WG-FSA starting in 2008.

REFERENCES

Endicott, M. and D.J. Agnew. 2004. The survivorship of rays discarded from the South Georgia longline fishery. *CCAMLR Science*, 11: 155–164.

Hill, S.L., K. Reid, S.E. Thorpe, J. Hinke and G.M. Watters. 2007. A compilation of parameters for ecosystem dynamics models of the Scotia Sea – Antarctic Peninsula region. *CCAMLR Science*, 14: 1–25.

APPENDIX A

LIST OF PARTICIPANTS

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(Christchurch, New Zealand, 9 to 13 July 2007)

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APPENDIX B

AGENDA

Working Group on Statistics, Assessments and Modelling
(Christchurch, New Zealand, 9 to 13 July 2007)

1. Introduction
   - 1.1 Opening of the meeting
   - 1.2 Adoption of the agenda and organisation of the meeting

2. Parameter estimation
   - 2.1 Refinements of existing methods
   - 2.2 New methods

3. Assessment methods
   - 3.1 *Dissostichus* spp.
   - 3.2 *Champsocephalus gunnari*
   - 3.3 *Euphausia superba*
   - 3.4 By-catch species

4. Review of preliminary assessments for finfish
   - 4.1 Subarea 48.3
   - 4.2 Division 58.5.2
   - 4.3 Subareas 88.1 and 88.2
   - 4.4 Subareas 58.6/58.7 (Prince Edward and Marion Islands)
   - 4.5 Division 58.5.1 (Kerguelen Islands)

5. Evaluation of management strategies
   - 5.1 *Dissostichus* spp.
   - 5.2 *Champsocephalus gunnari*
   - 5.3 *Euphausia superba*

6. Future work
   - 6.1 Terms of reference
   - 6.2 Long-term work plan
   - 6.3 Other issues

7. Other business

8. Advice to the Scientific Committee
   - 8.1 WG-EMM
   - 8.2 WG-FSA
   - 8.3 Ad hoc WG-IMAF
   - 8.4 General

9. Adoption of report and close of meeting.

APPENDIX C

LIST OF DOCUMENTS

Working Group on Statistics, Assessments and Modelling
(Christchurch, New Zealand, 9 to 13 July 2007)

WG-SAM-07/1	Preliminary Agenda and Annotated Preliminary Agenda for the 2007 Meeting of the Subgroup on Assessment Methods
WG-SAM-07/2	List of participants
WG- SAM-07/3 Rev. 1	List of documents
WG-SAM-07/4	Preliminary investigations of an assessment model for skates and rays in the Ross Sea A. Dunn, S.M. Hanchet, S.L. Ballara and M.P. Francis (New Zealand)
WG-SAM-07/5	An updated descriptive analysis of the toothfish (*Dissostichus* spp.) tagging program in Subareas 88.1 and 88.2 for 2006/07 A. Dunn, S.M. Hanchet and S.L. Ballara (New Zealand)
WG-SAM-07/6	Revised input parameters and implications for the Antarctic toothfish (*Dissostichus mawsoni*) stock assessment in Subareas 88.1 and 88.2 A. Dunn and S.M. Hanchet (New Zealand)
WG-SAM-07/7	Comparison of estimators of effective sample size for catch-at-age and catch-at-length data using simulated data from the Dirichlet-multinomial Distribution S.G. Candy (Australia)
WG-SAM-07/8	Proposed methodology for the assessment of the exploratory fishery for *Dissostichus* spp. on BANZARE Bank (Division 58.4.3b) D.C. Welsford, A.J. Constable and G.B. Nowara (Australia)
WG-SAM-07/9	Update of the Antarctic toothfish stock assessment for the Ross Sea by means of the TSVPA separable cohort model D. Vasilyev, K. Shust, V. Babayan and T. Bulgakova (Russia)
WG-SAM-07/10	Extension of the development of a management procedure for the toothfish (*Dissostichus eleginoides*) resource in the Prince Edward Islands vicinity A. Brandão and D.S. Butterworth (South Africa)

WG-SAM-07/11	Preliminary assessment of the South Georgia ray populations D.J. Agnew, R. Mitchell, T. Carruthers, J. Roberts, R. Hillary and J. Pearce (United Kingdom)
WG-SAM-07/12	A spatial multi-species operating model of the Antarctic Peninsula krill fishery and its impacts on land-breeding predators É.E. Plagányi and D.S. Butterworth (South Africa)
WG-SAM-07/13	An assessment strategy evaluation framework for testing the application of a CASAL based management system to the HIMI fishery I.R. Ball and S.G. Candy (Australia)
WG-SAM-07/14	Rationale, structure and current templates of the Ecosystem, Productivity, Ocean, Climate (EPOC) modelling framework to support evaluation of strategies to subdivide the Area 48 krill catch limit amongst small-scale management units A. Constable (Australia)
WG-SAM-07/15	Lenfest Ocean Program Workshop 'Identifying and Resolving Key Uncertainties in Management Models for Krill Fisheries'

Other documents

SC-CAMLR-XXVI/BG/2	Report of the Third Meeting of the Subgroup on Acoustic Survey and Analysis Methods (Cambridge, UK, 30 April to 2 May 2007)
SC-CAMLR-XXVI/BG/3	Report of the Planning Meeting of the CCAMLR-IPY Steering Committee (Cambridge, UK, 2 to 4 May 2007)